

DOUBLE SCALING OF ANGULAR CORRELATIONS INSIDE JETS ^a

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Angular correlations of partons have been derived for high energy jets in QCD. Interesting new scaling properties with two redundant variables (jet energy P and jet opening angle Θ) emerge which can be tested within a parton-hadron duality picture. Recent results from LEP support the scaling in Θ ; the scaling in both P and Θ could be tested with jets from deep inelastic scattering or with high p_T jets.

1 Introduction

There are indications that there is a soft confinement mechanism which does not lead to large rearrangements of momenta during the hadronisation process, so that QCD predictions on multiparton final states can be meaningfully compared with predictions on hadronic final states^{1,2}. An extreme possibility is the hypothesis of “Local Parton Hadron Duality” (LPHD)³, according to which the parton cascade

The energy spectra of particles gave initial support for this idea, in that they showed the same depletion for soft particles as did the spectra of particles due to the soft gluon interference^{3,4}. Also the effect of the running of α_s is clearly visible in the energy spectra⁵. It is therefore important to test these ideas for other quantities as well, in particular multiparticle observables.

Recently we have studied the properties of angular correlations in jets within the double logarithmic approximation (DLA) of QCD which provides the leading order results at high energies⁶. We derived explicit expressions for various two- and multiparton observables. Here we will report on some general scaling and universality properties of our results which follow from the QCD cascade with angular ordering.

Results partly overlapping with ours have been also obtained by other groups using somewhat different theoretical approaches, on angular correlations, in particular azimuthal correlations⁷ and on multiplicity moments^{8,9}.

2 Theoretical scheme

We start from an integral equation for the generating functional in DLA^{10,2} from which the properties of the cascade can be derived. It takes into account the leading collinear and soft divergencies but neglects recoil effects.

This yields the correct high energy asymptotic predictions and we investigated to what extent these predictions apply to present energies by comparing with the more complete MC¹¹ calculations. We derive from the generating functional the general n -parton cumulant correlation function $\Gamma^{(n)}(\Omega_1, \dots, \Omega_n)$ in the spherical angles Ω_i . Simpler quantities are obtained by partial integration. Finally we checked the backward consistency of our results by full integration, so our two parton correlation $\Gamma^{(2)}$ integrates to the global multiplicity moment $C_2 = F_2 - 1 = \langle n(n-1) \rangle / \langle n \rangle^2 - 1 = 1/3$, the well-known DLA result.

3 Scaling results

We consider the distribution $\rho^{(2)}(\vartheta_{12}, P, \Theta)$ in the relative angle ϑ_{12} between two partons inside a cone of half opening angle Θ around the primary parton of momentum P , also the quantity $\hat{r} = \rho^{(2)}/\bar{n}^2$ normalized by the average multiplicity \bar{n} in the cone or $r = \rho^{(2)}/\rho_{\text{norm}}^{(2)}$, where $\rho_{\text{norm}}^{(2)}$ is constructed from uncorrelated pairs (“event mixing”). We find that this correlation function, after an appropriate rescaling depends on the three variables ϑ_{12} , P and Θ only through the single variable $\varepsilon(\vartheta_{12}, P, \Theta)$

$$\frac{\ln r(\vartheta_{12}, \Theta, P)}{2\beta\sqrt{\ln \frac{P\Theta}{\Lambda}}} = \omega(\varepsilon, 2) - 2\sqrt{1-\varepsilon} \quad (1)$$

$$\varepsilon = \frac{\ln \frac{\Theta}{\vartheta_{12}}}{\ln \frac{P\Theta}{\Lambda}} \quad (2)$$

The function $\omega(\varepsilon, 2)$ determines the exponential growth of $\rho^{(2)}$ and the second term in (1) of $\rho_{\text{norm}}^{(2)}$. The function $\omega(\varepsilon, n)$ enters the n -parton correlation function and is exactly calculable, also various approximate forms are known⁶. The rescaling factor in (1) determines the exponential growth of multiplicity and can also be written as $\ln \bar{n} = 2\beta\sqrt{\ln \frac{P\Theta}{\Lambda}}$ where $\beta^2 = 4N_c/(11N_c/3 - 2N_f/3)$

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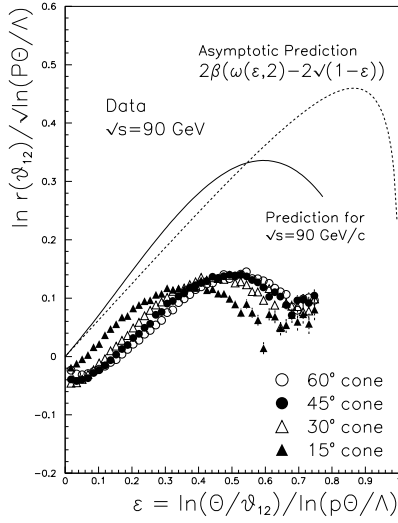
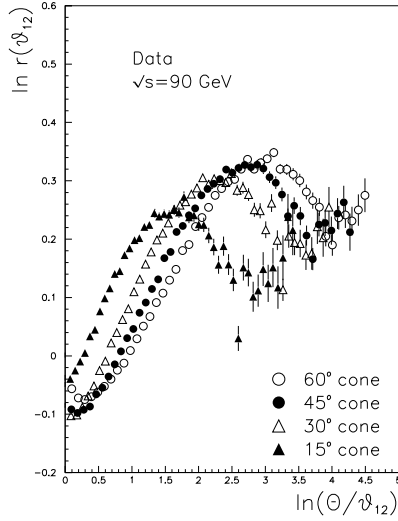


Figure 1: (a) Correlation in the relative angle ϑ_{12} in the forward cone of half opening angle Θ , for different Θ (b) the same, but in rescaled coordinates, “ ε scaling” (preliminary data from DELPHI).

and Λ is the QCD scale parameter. The variable ε can be viewed as a rescaled angle $\vartheta_{12} > \Lambda/P$ and therefore $\varepsilon < 1$. The scaling law (1) could then also be written as

$$\frac{\ln r(\vartheta_{12}, \Theta, P)}{\ln \bar{n}(\Theta, P)} = \chi(\varepsilon). \quad (3)$$

In a recent analysis by the DELPHI collaboration at LEP ¹² this new scaling property has been verified for jet opening angles in a range $30^\circ < \Theta < 60^\circ$, for smaller angles $\Theta \sim 15^\circ$ the scaling is violated; in this range the sensitivity to the jet direction (sphericity axis) becomes important (see Fig. 1). The sensitivity to the jet direction could be reduced by studying the corresponding Energy-Multiplicity-Multiplicity Correlations (EMMC) in which all particles serve in turn as jet axis with weight E_i of their energy ¹³. Our analytical DLA predictions re-

produce roughly the shape of the distribution but not the normalization which appears at nonleading order in the exponent. The correlation $\hat{r}(\varepsilon)$ defined above has shown better scaling properties in primary energy P in our MC calculations. The data ¹² show already a reasonable agreement with our analytical predictions at present energies.

It will be very interesting to test the double scaling in ε by varying in the same experiment the jet opening angle Θ and the jet energy P . Recent results from HERA on energy spectra in the Breit frame ¹⁴ have been well described by QCD calculations as in the e^+e^- -studies. The correlation data from deep inelastic scattering and also from high p_T jets are therefore well suited to further establish the scaling properties of the underlying parton cascade structure as derived from perturbative QCD.

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